

Exhibit A



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Arseneau

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(54) **PORTABLE ON VEHICLE DYNAMOMETER**

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G01M 17/007 (2006.01)

(52) **U.S. Cl.**
USPC **73/116.05**

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73/116.02, 116.05, 116.06, 116.08, 116.09,
73/116.11

See application file for complete search history.

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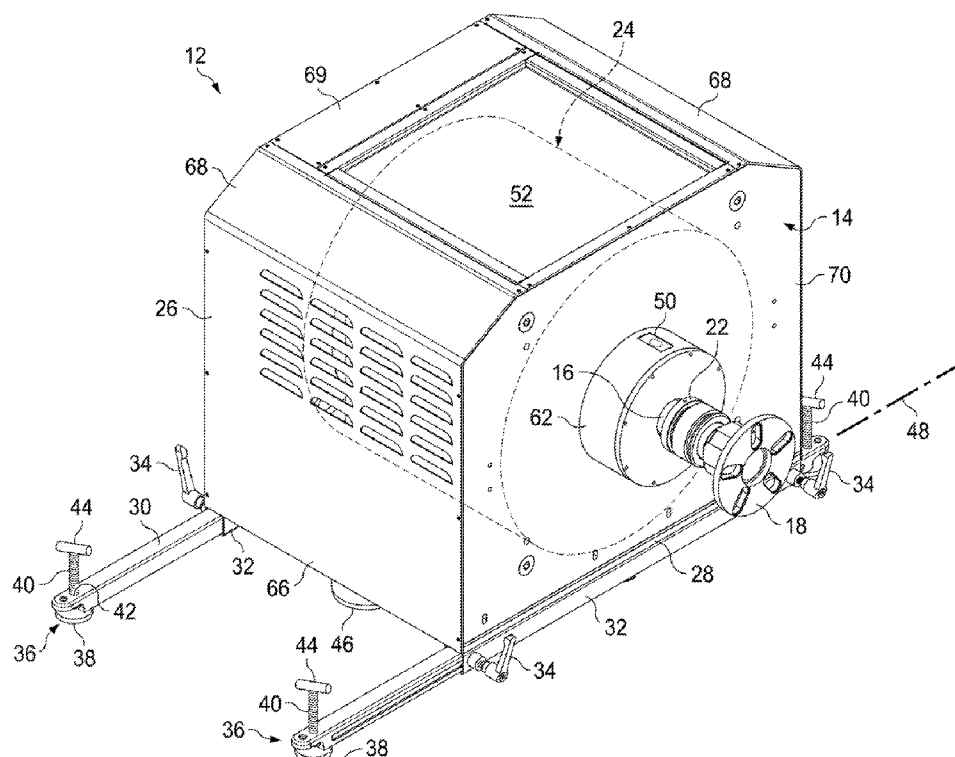
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(57) **ABSTRACT**

A portable on vehicle dynamometer (12) has a rigid frame (64), a load shaft (16), and an eddy current brake (24) with a stator (56) connected to the rigid frame (64) and a rotor (54) connected to the load shaft (16). A hub coupling (18) is secured to a first end of the load shaft (16) and connected to the drive shaft. The rigid frame (64) has two outwardly extending support arms (30) for securing in outwardly extending, fixed positions. Two roller assemblies (46) are mounted to a lower end of the rigid frame (64) for multidirectional movement of the dynamometer (12). Preferably the eddy current brake (24) comprises a cylindrically-shaped rotor drum (54) extending exteriorly around the stator (56), and the stator (56) comprises a plurality of stator coils (94) extending exteriorly around the load shaft (16), spaced apart from an interior of the rotor drum (54).

6 Claims, 13 Drawing Sheets

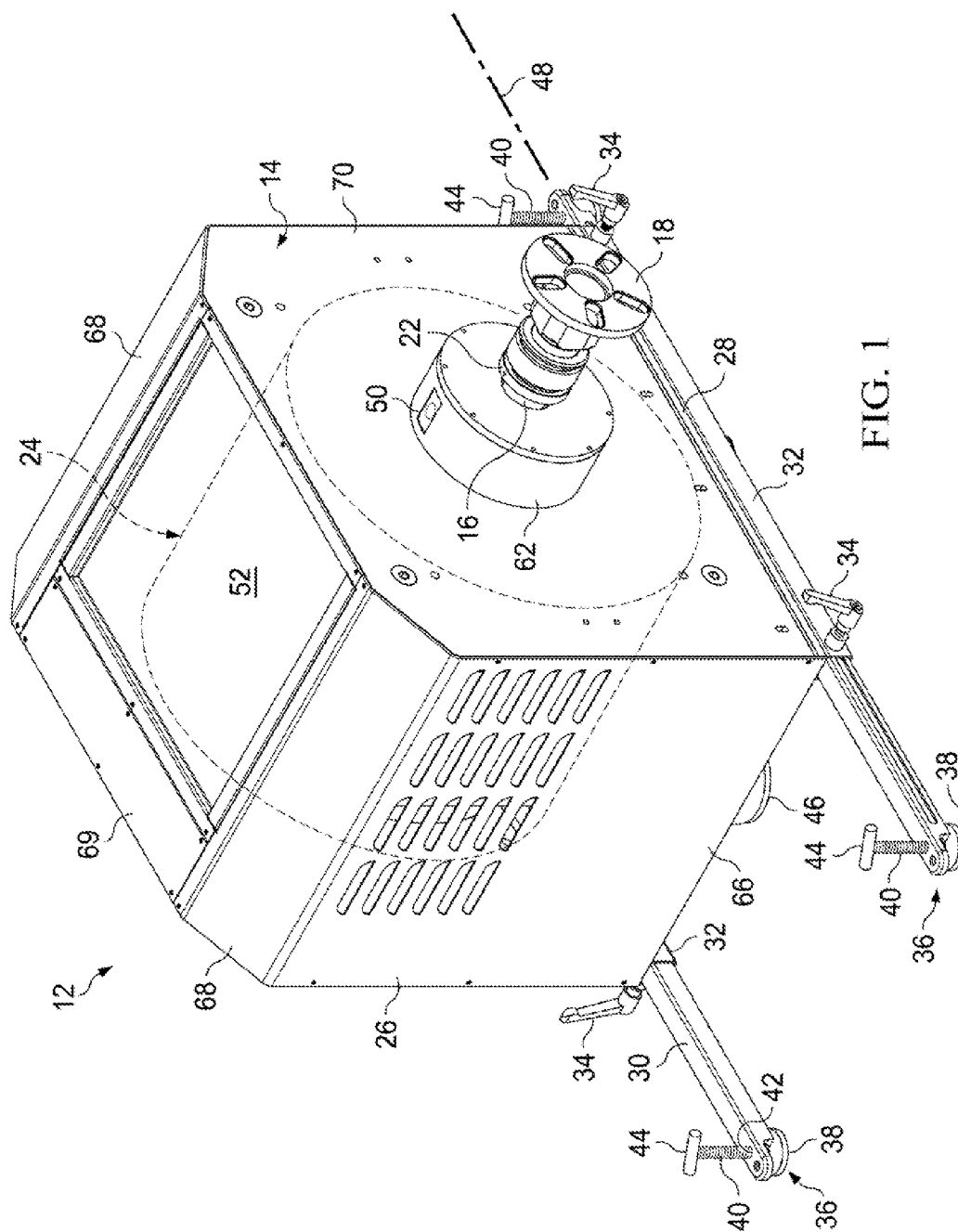


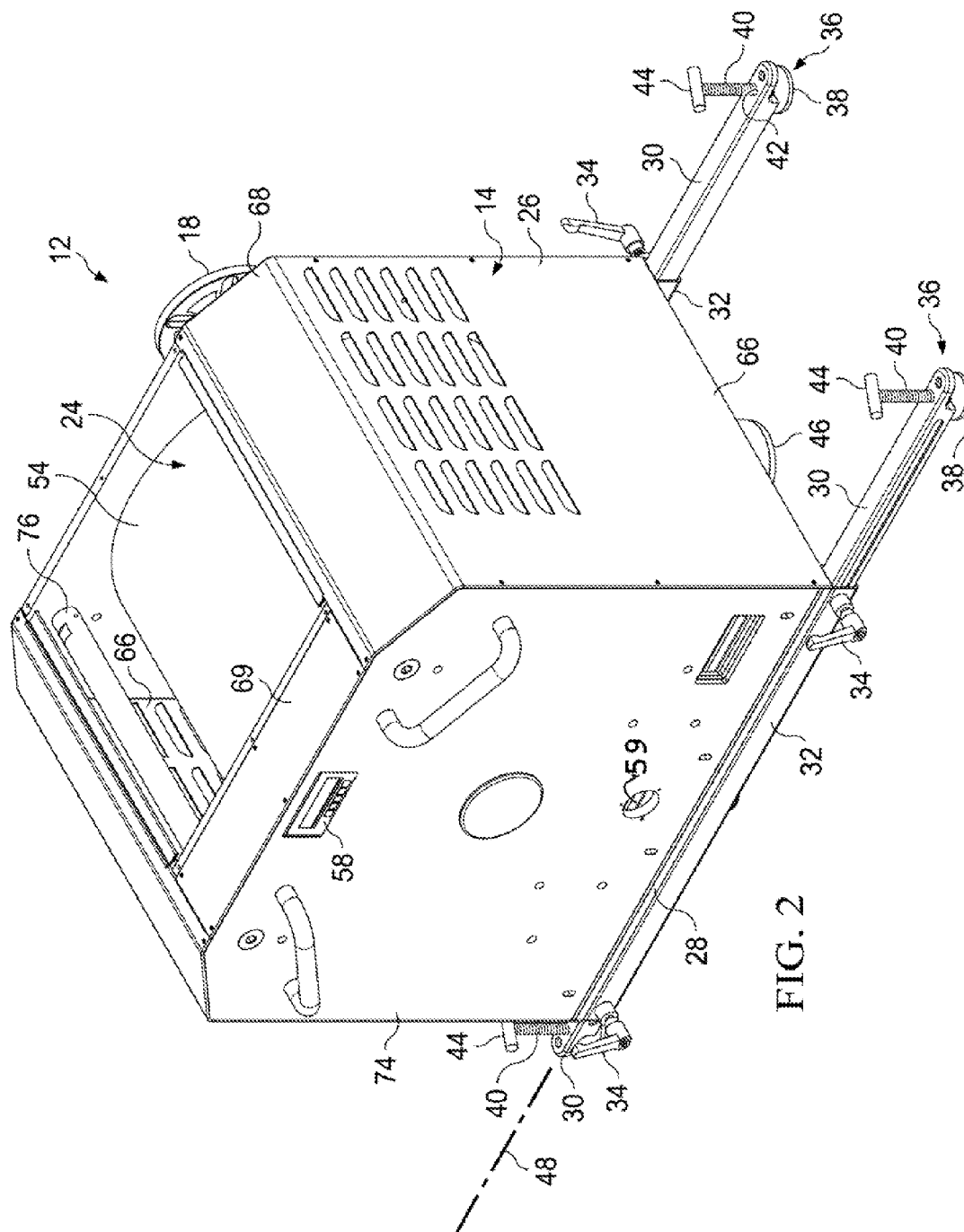
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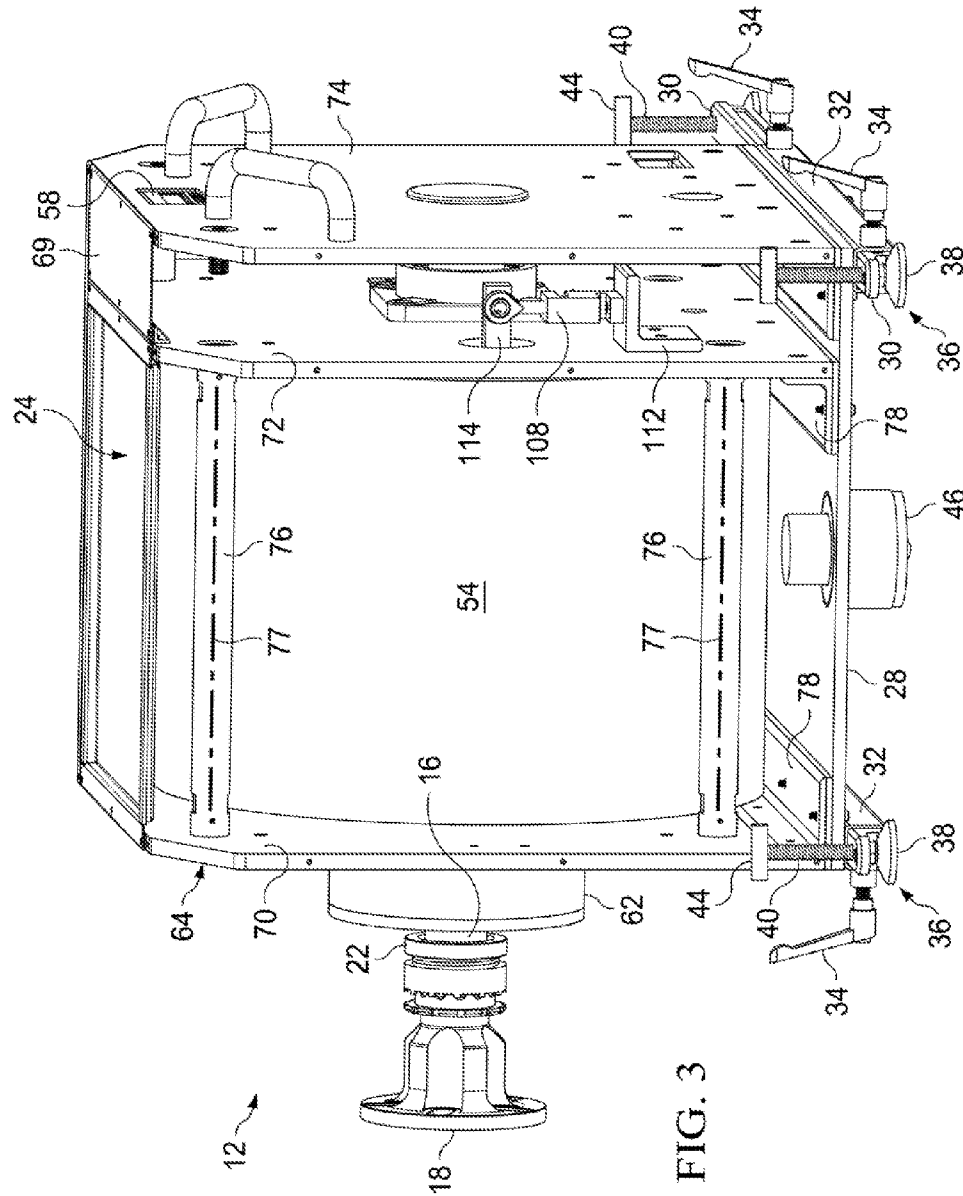
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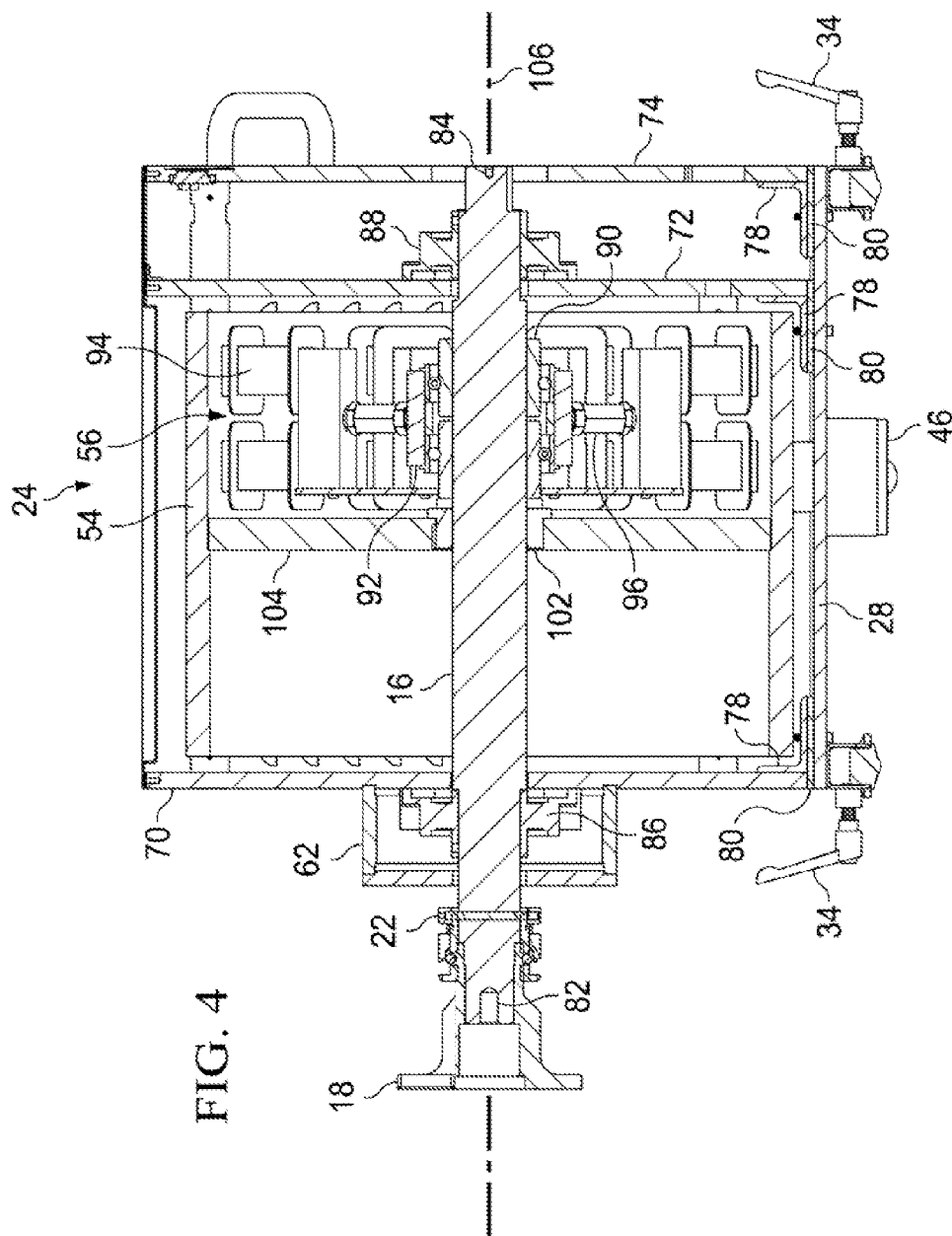
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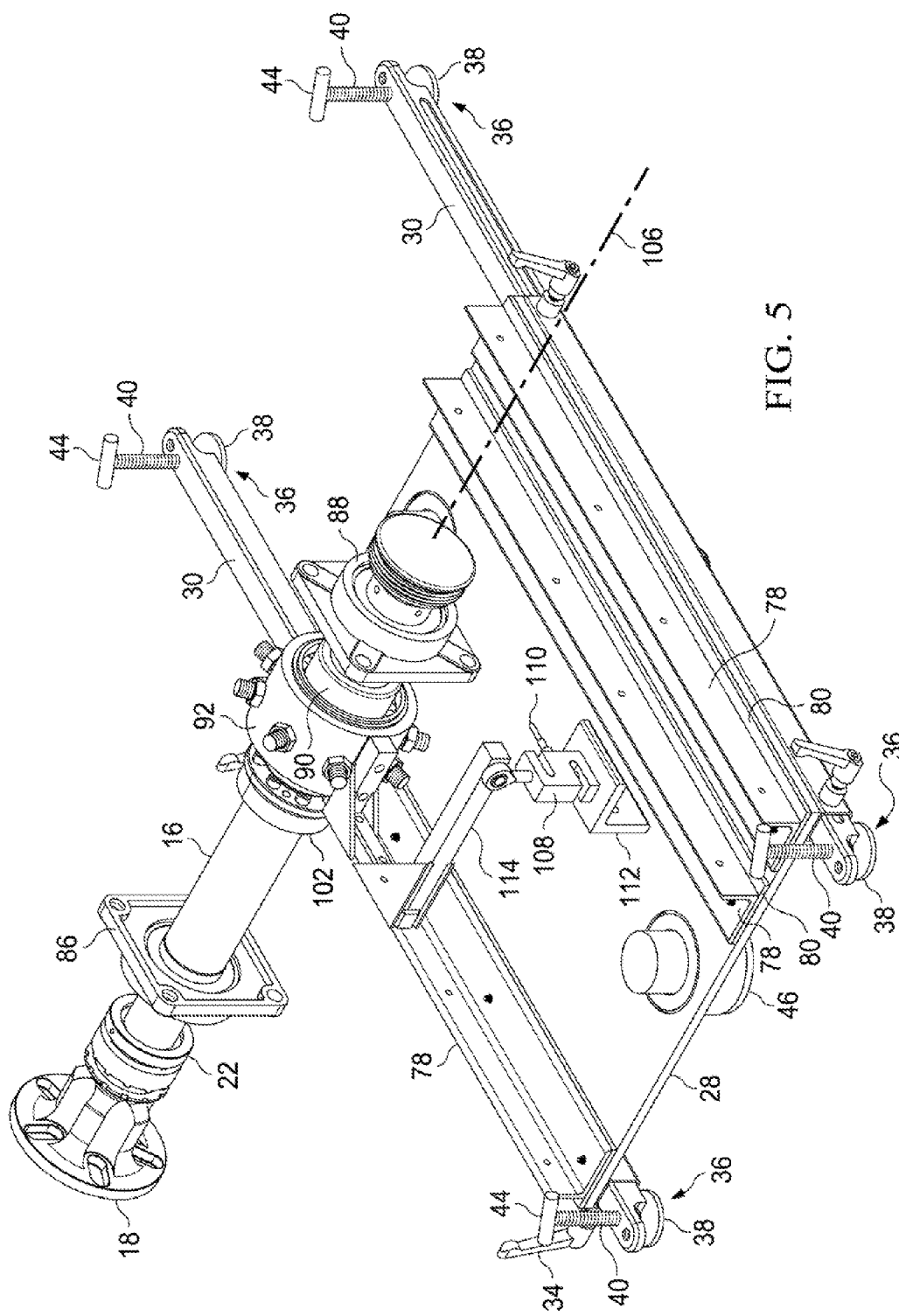


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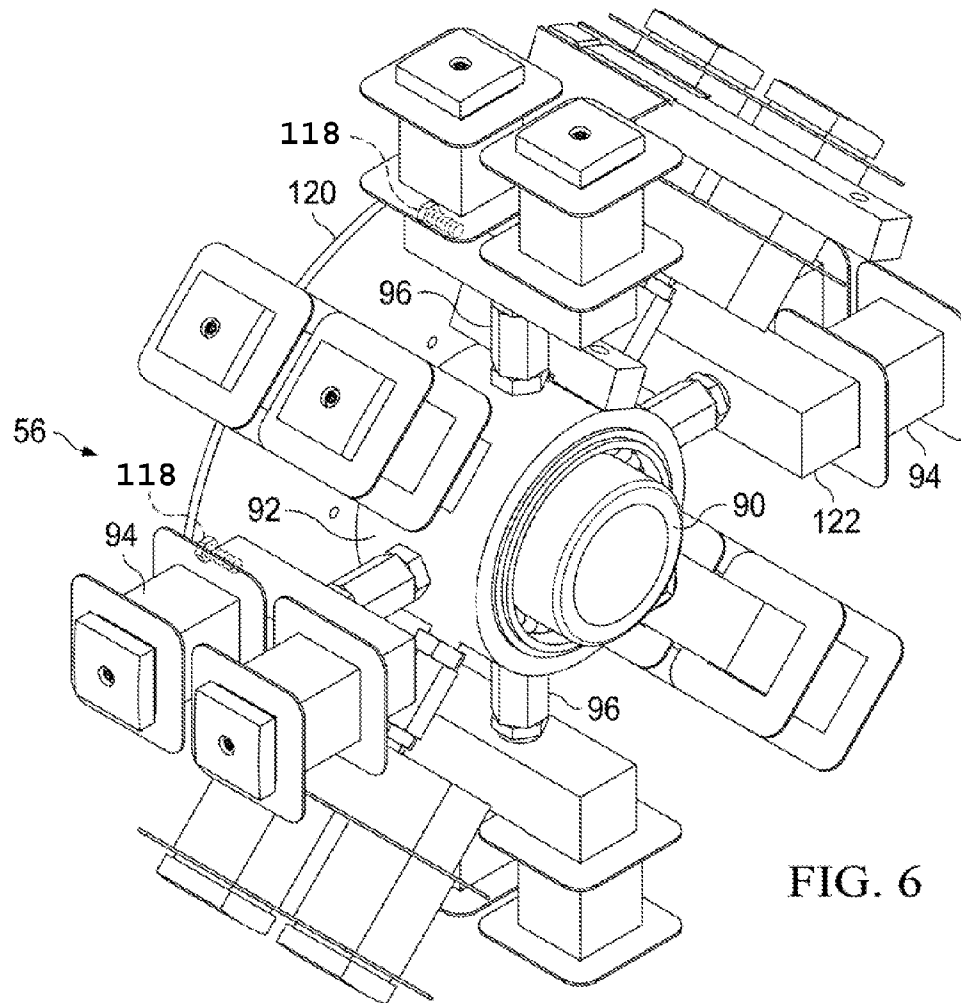


FIG. 6

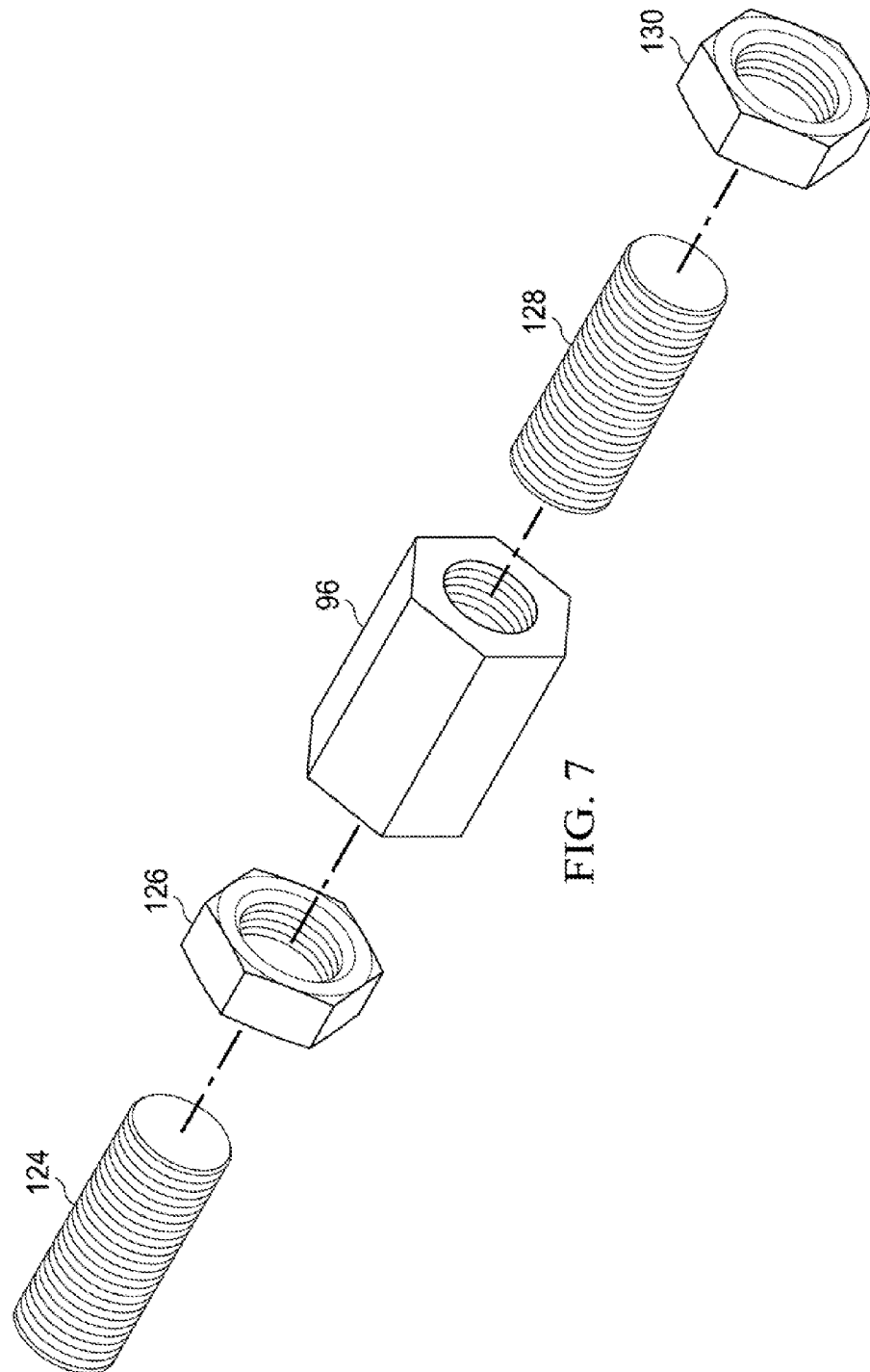


FIG. 8

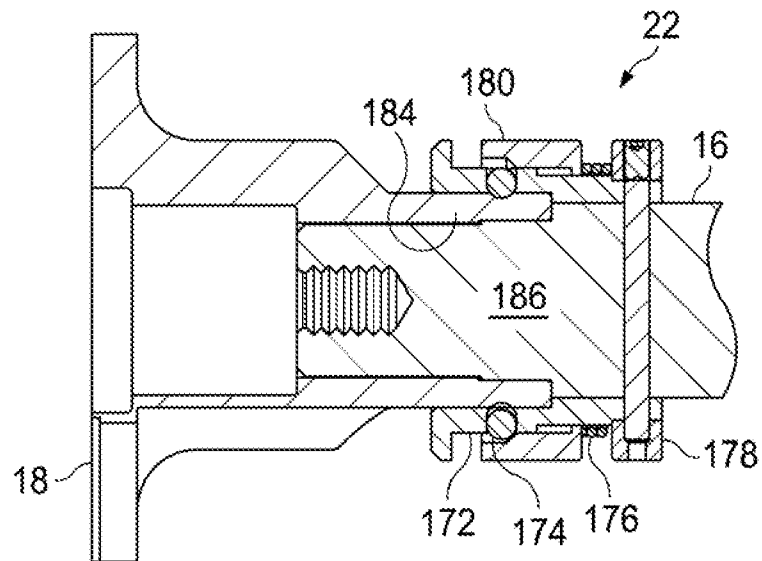
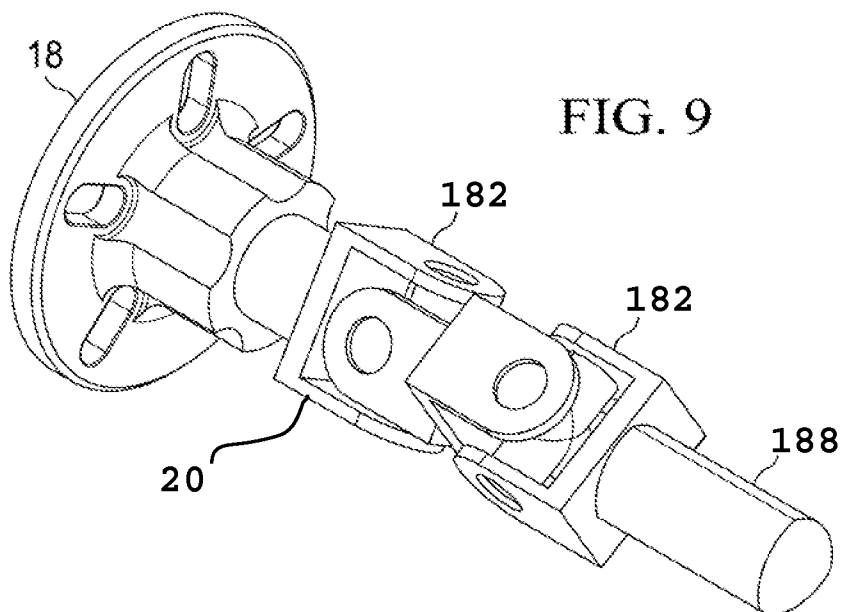


FIG. 9



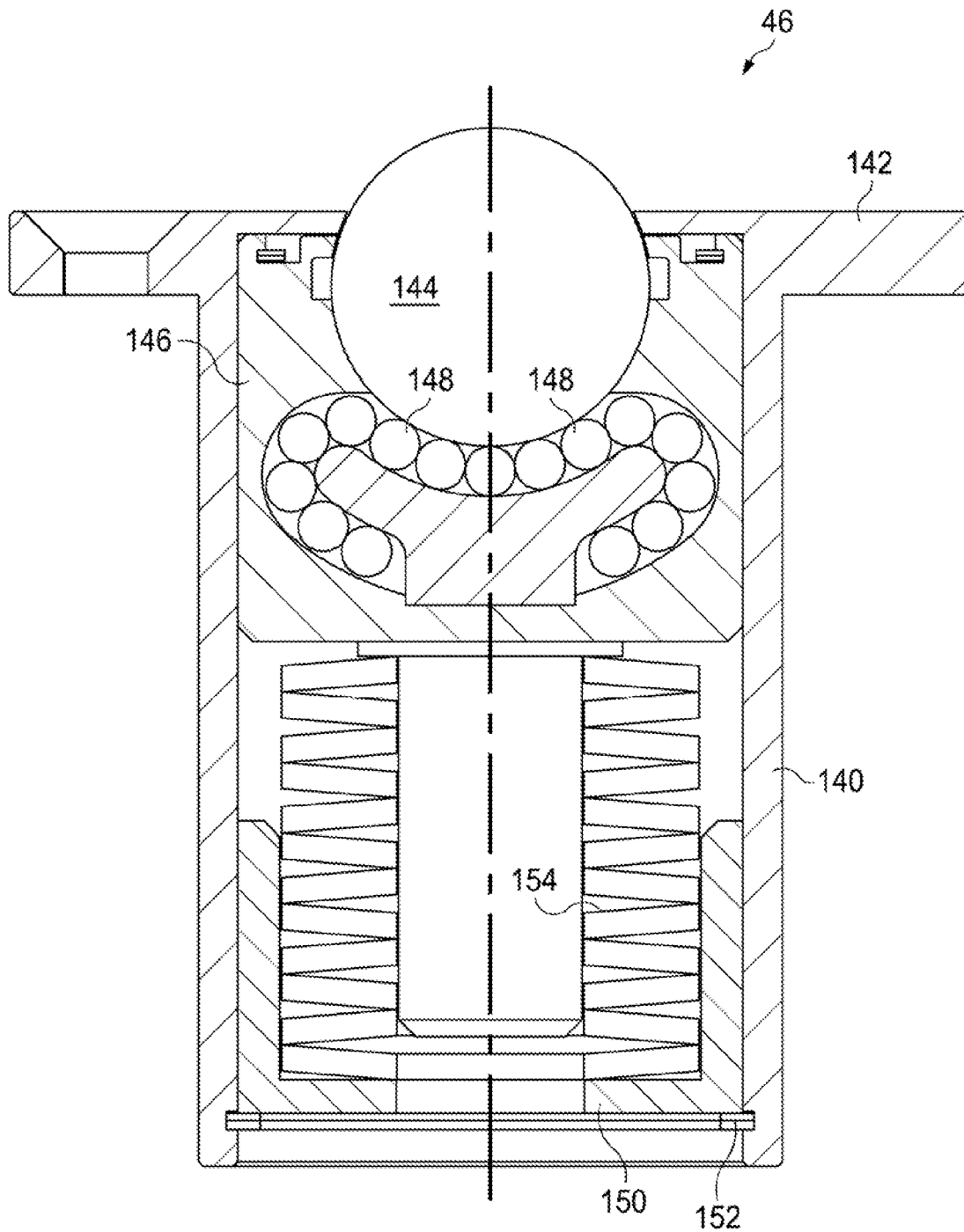


FIG. 10

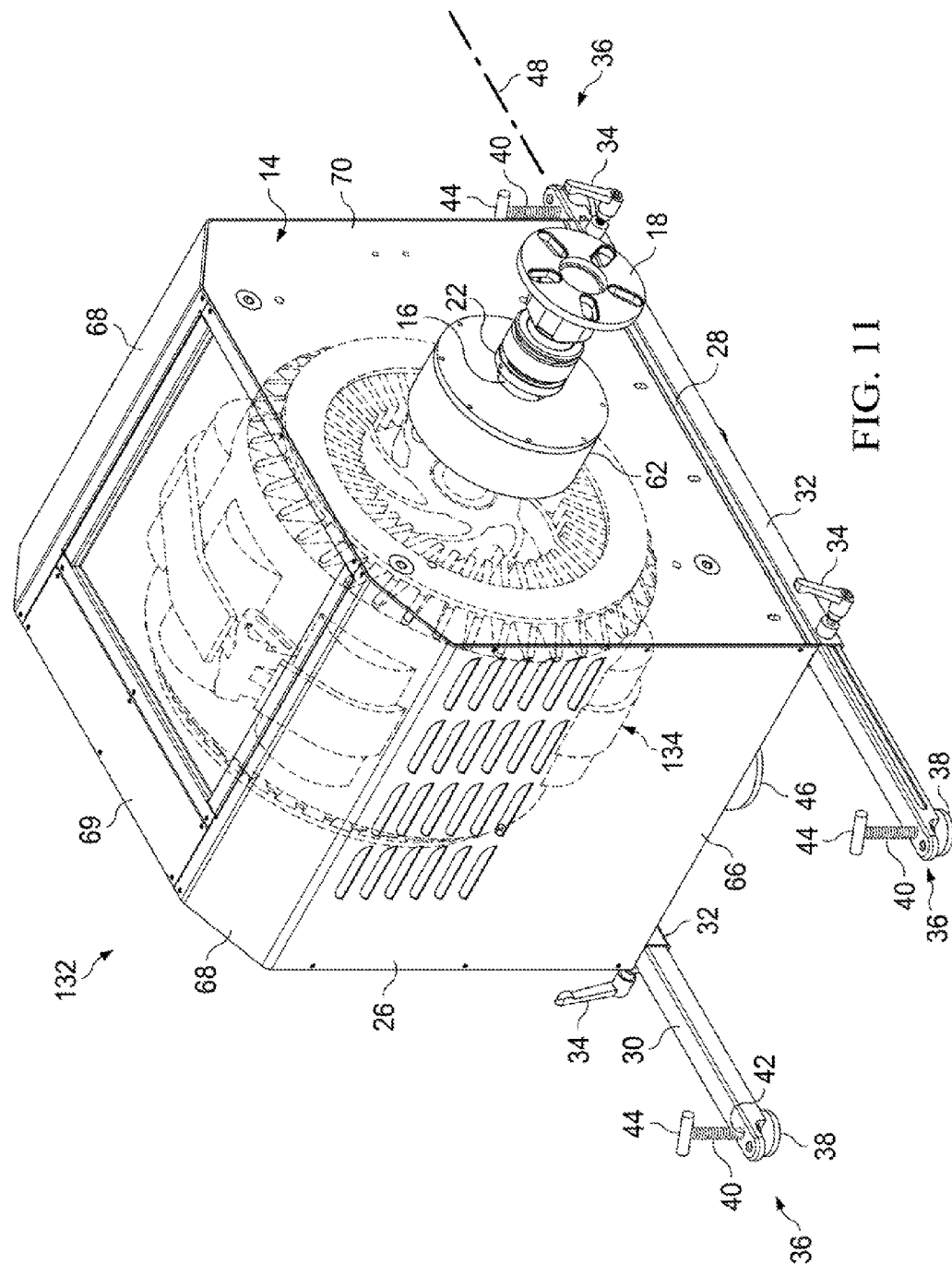
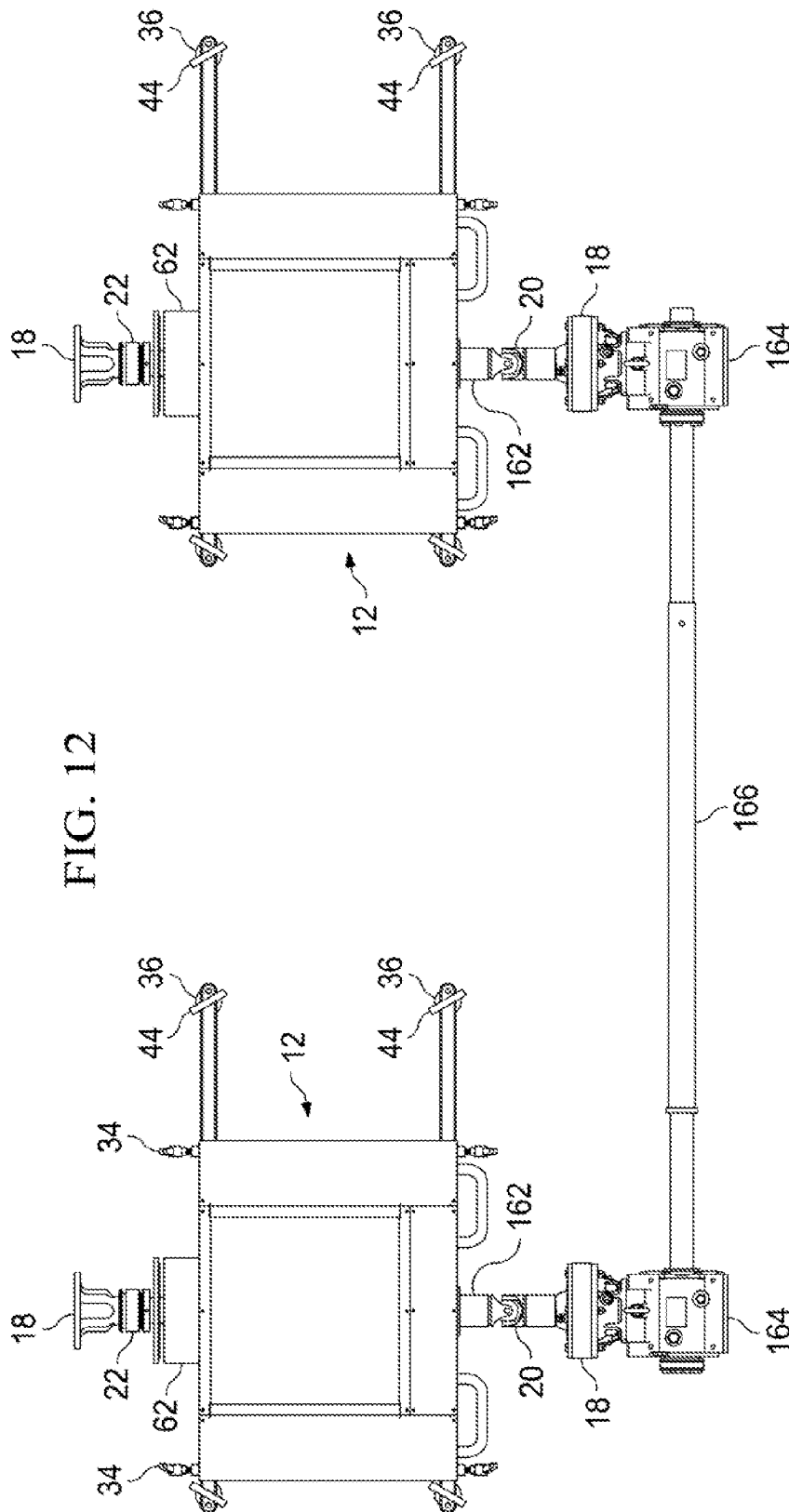
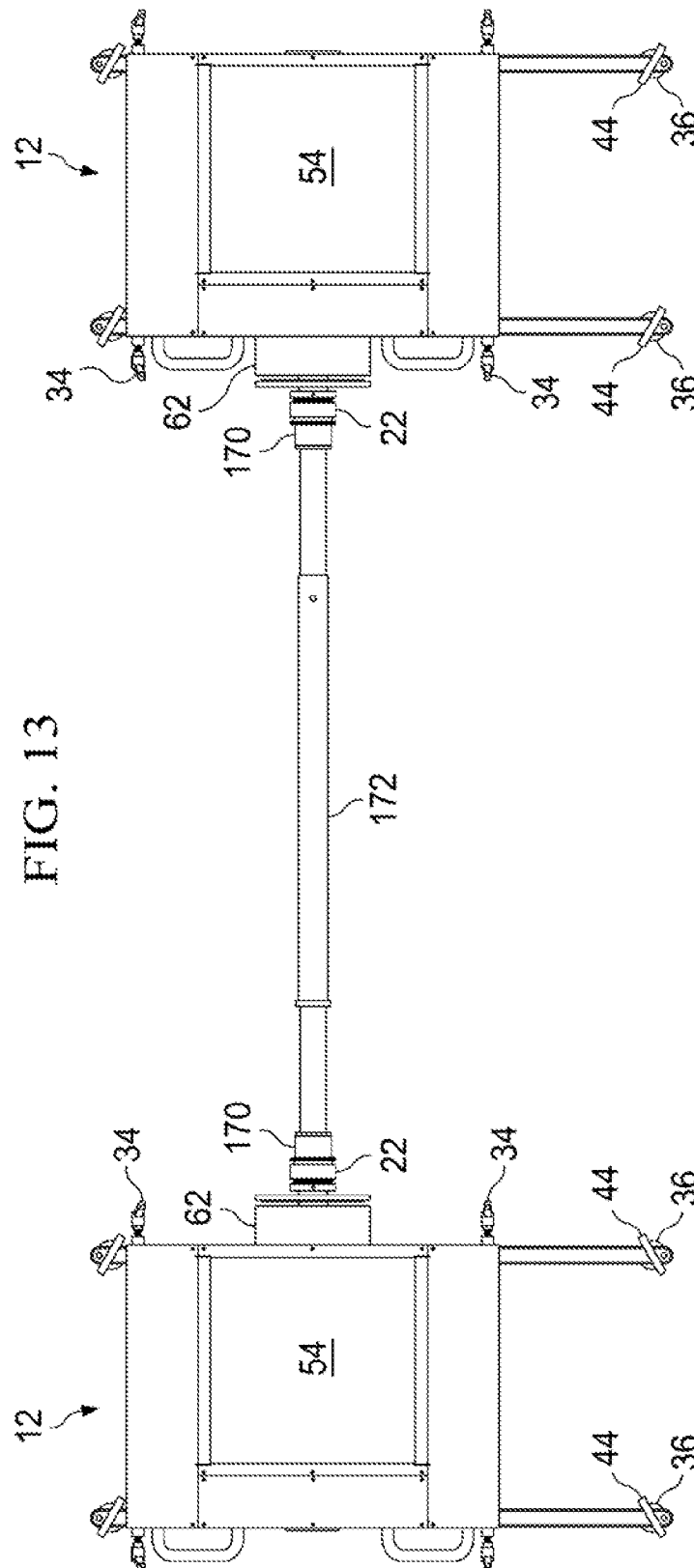
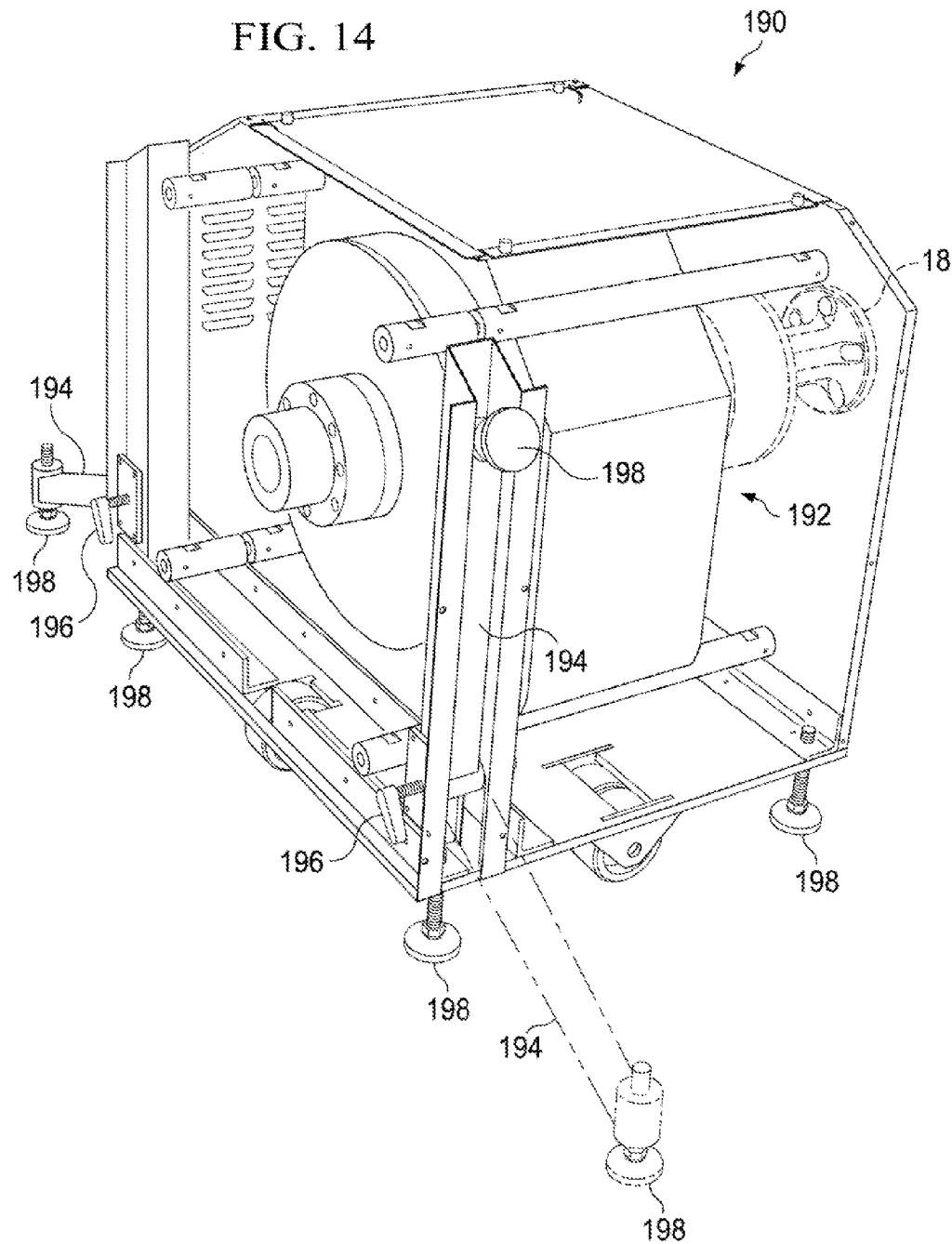


FIG. 12







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PORTABLE ON VEHICLE DYNAMOMETER**TECHNICAL FIELD OF THE INVENTION**

The present invention relates in general to dynamometers, and in particular to a dynamometer for coupling directly an output shaft for measuring power transmitted by the output shaft.

BACKGROUND OF THE INVENTION

Prior art dynamometers have been provided for measuring the power output from drive shafts, such as those for motor vehicles. Typical automotive chassis type dynamometers have rotary drums on top of which the wheels of vehicles are placed. Power is then transferred from an engine, to a drive shaft, to the wheels of the vehicle and then to the rotary drum of the chassis dynamometer. This type of dynamometer requires that the dynamometer either be buried in a garage floor, or that a rack is provided to suspend a vehicle above the dynamometer. Such configurations take up considerable space, and may not be often used. Considerable garage space is also used when hydraulic dynamometers are used, due to the ancillary hydraulic equipment required.

SUMMARY OF THE INVENTION

A portable on vehicle dynamometer ("POD") is provided for determining power output from a drive shaft. The POD has a rigid frame, a load shaft, and an eddy current brake. The eddy current brake has a stator connected to the rigid frame and a rotor connected to the load shaft. The stator is secured around an exterior of the drive shaft. A hub coupling is secured to a first end of the load shaft and connected to the drive shaft for transferring power to the load shaft. The rigid frame has two outwardly extending support arms and arm locks which secure the outwardly extending support arms in fixed positions. Support feet assemblies are mounted to respective ones of outer ends of the support arms. Two roller assemblies are mounted to a lower end of the rigid frame and provide for multidirectional movement of the dynamometer. Preferably the eddy current brake comprises a cylindrically-shaped rotor drum extending exteriorly around the stator, and the stator comprises a plurality of stator coils extending exteriorly around the load shaft, spaced apart from an interior of the rotor drum.

DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying Drawings in which FIGS. 1 through 14 show various aspects for portable on vehicle dynamometer devices made according to the present invention, as set forth below:

FIGS. 1 and 2 are perspective views of a portable on-vehicle dynamometer ("POD");

FIG. 3 is a perspective view of the POD with cover panels removed;

FIG. 4 is a longitudinal section view of the POD;

FIG. 5 is partial perspective view internal components for the POD;

FIG. 6 is a perspective view of a stator for use in the POD;

FIG. 7 is an exploded perspective view of mechanism for adjusting the gap between stator coils and a rotary drum for the POD;

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FIG. 8 is a sectional view of a quick connect for the load shaft of the POD;

FIG. 9 is a perspective view of a double universal coupled for mounting to the load shaft of the POD;

FIG. 10 is a sectional view of the roller assembly for the POD;

FIG. 11 is a perspective view of an alternative POD having a conventional eddy current brake mounted therein;

FIG. 12 is a top view of two PODS which are secured together for securing to two separate axles for determining the combined power output from the two separate axles;

FIG. 13 is top view of two PODS which are secured together for use in a conventional chassis type dynamometer configuration; and

FIG. 14 is an alternative POD having angled support arms which pivotally extend to provided support for the POD.

DETAILED DESCRIPTION OF THE INVENTION

FIGS. 1 and 2 are perspective views of a portable on-vehicle dynamometer ("POD") 12 for coupling directly to an axle of the vehicle to measure the power output of the axle. The POD 12 has a housing 14 from which extends a load shaft 16. The load shaft 16 is secured with a hub coupling 18, a universal joint 20, and a quick connect 22 to an eddy current brake 24. The eddy current brake 24 preferably is of the type having a stator 56 and a rotor drum 54, but in some embodiments other types of eddy current brakes may be used, such as the eddy current brake 134 shown in FIG. 11. A hub of a wheel of a vehicle may be connected directly to the hub coupling 18 for connecting the vehicle directly to the POD 12 to determine the power output of the vehicle, without requiring jack stands and the like to support the vehicle over a conventional type dynamometer.

FIG. 3 is a perspective view of the POD 12 with two cover panels 66 and 68 removed. The housing 14 defines an enclosure 26 having a base 28. The base 28 is preferably provided by a rigid steel plate. Two receiver tubes 32 are mounted to opposite ends of a lower side of the base 28 and extend in parallel in longitudinal alignment. Four support arms 30 extend outward from open ends of the receiver tubes 32. The four support arms 30 have longitudinal axes 48 which extend parallel to a major plane of the steel plate providing the base 28. Arm locks 34 are provided for securing the support arms 30 in retracted and in extended positions. Feet assembly 36 are mounted to the outward ends of the support arms 30 and extend downward for vertically engaging a floor or a ground surface located beneath the POD 12. The feet assembly 36 have feet 38 for engaging the floor or the ground surface. The feet 38 are mounted to a lower end of a rod 40. The rod 40 extends upward from the feet 38 and fit within threaded apertures 42 formed to extend vertically within the support arms 30. In some embodiments, sleeves may be welded or otherwise secured to the outward ends of the support arms 30 to provide the threaded apertures 42. Grip handles 44 rigidly secured to respective ones of the upper ends of the rods 40 for use in turning rods 40 to extend and retract the feet assembly 36 from the outward ends of the support arms 30. The feet assembly 36 preferably have longitudinal axes defined by the rods 40 which extend perpendicular to the longitudinal axis 48 of the support arms 30 and the receiver tubes 32. Two roller assemblies 46 are mounted to the bottom of the base plate 28, spaced apart in intermediate positions between the support arms 30. The upper end of the housing 14 has a removable tray 52. Tray 52 once removed exposes a rotor drum 54 which is connected to the load shaft 16. With the tray 52 removed, a tire mounted to a wheel of a motorcycle wheel or automobile may

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be directly placed upon the rotor drum **54** and the POD used in conventional fashion as a dynamometer. An electric connector **58** is provided on the exterior of the POD **12** for electrically connecting the POD **12** to test equipment for determining torque, speed and power output applied to load shaft **16**. An electrical plug **59** is provided to supply electrical power when the eddy current brake **24** is in use.

The housing **14** has a frame **64** defined by the base plate **28**, two bearing plates **70** and **72**, and the end plate **74**. The end plate **74** is mounted to an outward end of the base plate **28**, and also provides a bearing plate when the outward end of the load shaft is used for connecting between PODS **12**, as shown in FIGS. **12** and **13**. Vented cover panels **66** are mounted to opposite sides of the frame **64**. Cover panels **68** and **69** are provided for enclosing the frame **64**. The four support rods **76** extend between the bearing plates **70** and **72** and optionally to the end plate **74** to provide a rigid support between the bearing plates **70** and **72**, and the end plate **74**. The support rods **76** have longitudinal axes **77** which preferably extend parallel to the upper surface of the base plate **28** and perpendicular to major planes of the bearing plates **70** and **72**, and the end plate **74**. Mounting brackets **78** are provided by angle iron sections for securing the bearing plates **70** and **72** and the end plate **74** in fixed, upright positions relative to the base **28**. Rubber isolators **80** are provided by flat sheets of rubber, preferably one-quarter inch thick neoprene of sufficient stiffness for dampening, which are disposed between the supports **78** and the upper surface of the base plate **28** to dampen vibration there-between.

FIG. **4** is a longitudinal section view and FIG. **5** is a partial perspective view of the POD **12** showing the load shaft **16** and support bearings **86** and **88** for the load shaft **16**. The bearing **86** is mounted to the bearing plate **70** at the forward end of the POD **12**. The bearing **88** is mounted to the bearing plate **72** toward the rearward end of the POD **12**. The bearing **86** is preferably a double taper roller bearing for both thrust and axial loads. The bearing **88** is preferably either a roller bearing or a spherical ball bearing, but in some embodiments may also be a double taper roller bearing. The end plate **74** is provided for mounting a bearing for securing the outward end of the load shaft **16** to a second load shaft of a second POD. As shown in FIGS. **12** and **13**. A bearing cover **62** is mounted to the exterior of the bearing plate **70** to cover the bearing **86**. A bubble level **50** is mounted to the bearing cover **62** for leveling the POD **12**. A stator bearing **90** is mounted around the load shaft **16** for rotatably securing the stator **56** around the load shaft **16**. A mounting ring **92** is secured to the outer sleeve of the bearing **90**. Stator gap adjustment sleeves **96** secure the stator coils **94** to the mounting ring **92**. A coupling **102** is provided for securing a rotor plate **104** to the load shaft **16**. The rotor plate **104** is a rigid plate which preferably extends with a major plane perpendicular to the longitudinal axis **106** of the load shaft **16** and the rotor drum **54**. The rotor plate **104** secures the rotor drum **54** in fixed relation to the load shaft **16**. The load shaft **16** and the rotor drum **54** both preferably have cylindrical exterior surfaces, with the load shaft **16** concentrically disposed within the rotor drum **54**. The drum **54** is preferably made of ferrous materials and provides the rotor for the eddy current brake **24**.

A load cell **108** is provided for securing the stator **56** in fixed relation relative to the housing **14**. An electrical connector **110** is provided for connecting the load cell **108** to control and test circuitry for determining the power applied to the POD **12** by a power output shaft connected to the POD **12**. The load cell **108** is used for determining the torque required to maintain the stator **56** in a fixed position. In the preferred embodiment a piezoelectric material is used to determine

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deformation of the load cell **108** under load. In other embodiments, a strain gauge may be used. The load cell **108** is connected to a load cell mounting bracket **112**. The mounting bracket **112** is secured to a rearward side of the bearing plate **72**. The other end of the load cell **108** is connected to a first end of a support arm **114**. A second end of the support arm **114** is connected to the mounting ring **92** to which the stator **56** is secured. The stator **56** is maintained in a stationary position with respect to the bearing plate **72** by the support arm **114**. A stator plate **102** is mounted to a forward end of the stator **56**.

FIG. **6** is a perspective view of the stator **56**, and FIG. **7** is a perspective view of an adjustment sleeve **96** and lock nuts **126** and **130** for adjusting the gap between the stator coils **94** and the rotor drum **54**. The stator coils **94** are secured to the mounting ring **92** such that the coils may be extended and retracted relative to the mounting ring **92** to determine the gap between the stator coils **94** and the interior surface of the rotor drum **54**. A stator locking plate **120** is secured to the forward end of the bearing **90** and is secured to each of the u-shaped arms **122** by threaded connectors **118**. The threaded rods **124** provide pins which are threadingly secured to apertures in the mounting ring **92**. Preferably, the mounting ring **92** is cylindrical and apertures are drilled to extend radially through the circumference of the outer surface of the mounting ring **92**. Lock nuts **126** are threadingly secured to the threaded rods **124**. The stator gap adjustment sleeves **96** are threadingly secured to the outward ends of the threaded rods **124**. Threaded rods **128** are secured to the outward ends of the stator gap adjustment sleeves **96** and lock nuts **130** are secured to the outward ends of the threaded rods **128**. The threads on the rods **128** are of an opposite hand to the threads of the rods **124**, such that rotation of the adjustment sleeves **96** in one direction will extend the combined length of the coupled threaded rods **124** and **128**, and in a second angular direction will contract the combined length of the threaded rods **124** and **128**. The adjustment sleeves **96** may be secured in fixed relation with the lock nuts **126** and **130** once the gap between the stator coils **94** and the interior of the rotor drum **54** is disposed at a preferred distance.

FIG. **8** is a longitudinal section view of the quick connect **22**, which is mounted on a first end to the load shaft **16** and on a second end to the hub coupling **18**. The quick connect **22** has a tubular sleeve **172**, lock balls **174** which fit directly into radially extending apertures in the sleeve **172**, a bias spring **176**, a retainer **178** and a slip collar **180**. The slip collar **180** is biased into a forward position by the spring **176**. The end **186** of the load shaft **16** and the interior of the end **184** of the hub adapter **18** are formed of a shape to provide a polygon spline type configuration as shown in FIG. **9**.

FIG. **9** is a perspective view of a double universal joint **20** having two universal joints **182** in series, extending along a singular axis to provide two degrees of movement for misalignment. A first end has a hub coupling **18** mounted thereto. A second end **188** is formed to have a recess with a profile for providing a polygon-shaped tapered spline for coupling to a similar shape on the exterior of the end **82** of the load shaft **16**. In other embodiments, other coupling means may be used, such as keyed shafts, as preferably used on the outer end **84** of the load shaft **16**, or a traditional splined shafts having grooves and elongated ribs (not shown).

FIG. **10** is a longitudinal section view of the roller assembly **46**. The roller assembly **46** has a cylindrically shaped housing **140** having a mounting flange **142** on a lower end. The mounting flange **142** secures the roller assembly **46** to the underside of the base plate **28**. A support ball **144** extends outward of the lower end of the housing **142** for engaging a ground surface beneath the base plate **28** to support the weight of the POD **12**.

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A block **146** is disposed within the housing **140**, having an end which fits against the support ball **144**. A bearing assembly **148** is provided in the block **146** to allow the support ball **144** to move freely. A washer spring assembly **154** is provided in the upper end of the housing **140**. A retainer **150** secures the belleville washer spring assembly **154** in position. A retainer ring **152** secures the retainer **150** in position within the housing **140**.

FIG. **11** is a perspective view of an alternative POD **132** having a conventional eddy current brake **134** mounted therein, rather than the eddy current brake **24** shown in FIGS. **3** and **4**. The conventional eddy current brake **134** may be used in place of the eddy current brake **24** of FIGS. **3** and **4**, in other embodiments of the present invention.

FIG. **12** is a perspective view of two PODS **12** which are secured together for securing to two separate axles for determining the combined power output from the two separate axles of an all-wheel drive vehicle. The PODS **12** have connectors **162** which are secured to the outward ends of respective ones of the load shaft **16**. Ninety degree gear boxes **164** connect to the PODS **12** and are connected together by a coupling shaft **166**.

FIG. **13** is a top view of two PODS **12** connected together for use in typical fashion as a chassis dynamometer. The rotor drums **54** are exposed such that two drive tires may be placed directly atop the rotor drums **54** of the two PODS **12**. Two adapters **170** are provided on opposite ends of a connecting shaft **172** for connecting to the quick connects **22** and directly to the load shafts **16** of the two PODS **12**. The connecting shaft **172** is may be selectively extended and retracted to accommodate different spacings between the two PODS **12**.

FIG. **14** is a perspective view of an alternate configuration for a POD **190** having a conventional eddy current brake **192**, rather than a rotary drum which extends exteriorly around a stator having electric coils mounted to the stator. The POD **190** has two support legs **194** which are pivotally secured within a vertically disposed channel for storage, and then which may be extended downward for supporting the POD **190**. The support legs **194** have support feet **198** on the outward ends. Support leg locks **196** are threaded members which are tightened to secure the support legs **194** in downward positions during use of the POD **190**, and to retainer the support legs **194** in storage positions.

Thus the advantages of this invention provides a compact dynamometer which may be stored in small spaces when not in use. One POD can be used for a solid or live axle [locker spool type, in which both axles are locked]] vehicle where both wheels rotate with the same torque and speed or two pods are used where the axle of the car is a limited slip or similar type axle. In an all wheel drive scenario the front and rear pods have the capability to be mechanically linked together via a coupling and right angle gear box assembly or similar, using the opposite ends of the load shafts not connected to the wheel hub being tested. Support arms are extended to provide a wider footprint for the POD and assist in providing leverage for the torsional forces when in use. The support arms can be folded or retracted when not in use to allow for compact storage. The eddy current brake of the PODS according to the present invention may have sufficient rotor mass that the unit can be used as an inertia type dynamometer without having the eddy brake stator energized. The benefit of this is that if in an area without power, the system can be used to accelerate a known inertial mass of the rotor using and computing the torque and horsepower according to the formula: Torque=Inertia×Angular acceleration. The Inertia is known for the rotor drum, and the angular acceleration is calculated by a shaft encoder sensor. The POD can change angle to allow for misalignment in the vehicles suspension via leveling pads/feet and tilting or rotating among its castors/ball castors, and such. A tire for a motorcycle, ATV, or vehicle's tire can directly be place on rotor drum for the POD to function as traditional chassis dynamometer. The unit is compact enough to allow doors on a vehicle to open and close when bolted on the vehicle.

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Although the preferred embodiment has been described in detail, it should be understood that various changes, substitutions and alterations can be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

What is claimed is:

1. A portable on vehicle dynamometer for determining power output from a drive shaft, comprising:

- a rigid frame;
- a load shaft rotatably coupled to said rigid frame;
- an eddy current brake having a stator connected to said rigid frame, and a rotor connected to said load shaft;
- a hub coupling secured to a first end of said load shaft and connected directly to the drive shaft for transferring power to the load shaft, wherein said hub coupling, said drive shaft and said load shaft co-axially rotate;
- said rigid frame having two outwardly extending support arms, and arm locks which secure said outwardly extending support arms in fixed positions;
- support feet assemblies mounting to respective ones of outer ends of said support arms; and
- two roller assemblies mounted to a lower end of said rigid frame, providing multidirectional movement of said dynamometer.

2. The portable on vehicle dynamometer according to claim 1, wherein said rotor of said eddy current brake comprises a cylindrically-shaped rotor drum extending exteriorly around said stator, and said stator comprises a plurality of stator coils extending exteriorly around said load shaft, spaced apart from an interior of said rotor drum.

3. The portable on vehicle dynamometer according to claim 2, further comprising a stator bearing interiorly secured to said drive shaft and exteriorly secured to said stator.

4. The portable on vehicle dynamometer according to claim 3, wherein said eddy current brake is a conventional style eddy current brake, having eddy plates which extend perpendicular to said load shaft and face electric coils.

5. The portable on vehicle dynamometer according to claim 4, further comprising said rotor having sufficient mass for operation of said eddy current break without power to determine the power output from the drive shaft.

6. The portable on vehicle dynamometer according to claim 5, further comprising a quick-disconnect coupler for securing a hub adapter there-to for mating to drive shaft hub.

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